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The Relationship Between Computer Scoring and Safety-Pilot Grading of Flight Performance

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Three different measures of helicopter pilot performance were correlated--two types of computer scores and one type of safety/instructor pilot grades. Results indicated the two types of computer scores were basically interchangeable. The direction of the relationship between the different types of computer and safety-pilot measures was as expected for 76 percent of the measures examined, but statistical significance was attained in fewer cases (approximately 50 percent of the total). Reasons for any noted discrepancies are discussed along with findings about the most strongly associated measures. The computer scores and safety-pilot grades were related strongly enough to conclude that they were both accurately measuring the same type of performance.

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Introduction

The desirability of establishing automated, objective assessments of pilot performance stems from a requirement to: 1) improve performance evaluation accuracy, 2) establish a measurement strategy which can be used in the absence of a safety pilot, and 3) provide a reliable, bias-free indicator of the effects of different training approaches, stressors, or conditions on aviator performance. The task is complex, particularly because of the highly dynamic, multivariate characteristics of the flight environment. However, as Knoop and Welde (1973) point out, the problems are solvable given enough of the right sort of attention. Unfortunately, adequate measurement approaches often are viewed as luxuries rather than as necessities, and therefore, many questions about the evaluation of pilot performance remain unanswered.

A review by Lees and Ellingstad (1990) correctly summarizes the basic problem areas as: 1) determining what indexes of performance require measurement, 2) developing adequate tools to sample these indexes, and 3) deciding at what times to collect the measurement samples. Numerous investigators have addressed these problem areas, but there has been no consensus about exactly what the solutions should be. However, one rather widely used approach has been to establish a specific set of flight maneuvers, determine (through expert consensus) the relevant parameters, and measure the pilot's ability to maintain these parameters using objective and/or subjective evaluations.

Dellinger, Taylor, and Richardson (1986) compared the effects of atropine and ethanol on the simulator performance of pilots using a computerized measurement system. The subject pilots were required to fly instrument holding patterns and complete an instrument landing system (ILS) approach while the computer measured such variables as altitude control, turn rate, and localizer tracking. Root mean square (RMS) errors were calculated on each of the variables for each pilot in order to determine the amount of control deviation from specified standards, and analysis of these RMS errors permitted evaluation of drug effects.

Simmons et al. (1989) used a similar approach when investigating the effects of atropine sulfate on helicopter pilots' performance in a simulator, but in their study, both computer evaluations and safety-pilot ratings were used. In this case, subject pilots flew several maneuvers including a straight-and-level, a climbing turn, a descending turn, and an ILS while control of different parameters (heading, airspeed, altitude, etc.) was assessed. Performance was evaluated in terms of RMS errors, computer scores, and safety-pilot grades, each of which was able to detect drug-induced changes in performance.

Stein (1984) also utilized both computer scoring and safety-pilot grading of flight performance; however, his intention was to determine whether the methods could discriminate between master pilots and journeymen, rather than to evaluate the influence of a stressor (or drug). Stein reported that both performance evaluation methods were successful in discriminating between the two groups.

In view of these findings, it is feasible to accurately measure pilot performance at least during some subset of flight components. However, debate exists over whether a machine can assess pilot performance as well as an expert human observer. On the one hand, there is evidence that computers and safety pilots (or instructor pilots) simply do not produce the same evaluations of a pilot's performance, and this seems particularly a problem when several different safety pilots are used (Knoop and Welde, 1973). On the other hand, however, there is evidence that reasonable comparability between computer and human evaluations of flight performance does exist, particularly when a single, well-trained safety pilot controls automated data collection and concurrently makes subjective evaluations.

This report examines the relationship between computer scoring and safety-pilot grading of helicopter pilot performance under the influence of atropine sulfate. Two types of computer scores were derived: 1) a specialized percent score based on categorization of control deviations into specific error bandwidths; and 2) the more traditional RMS error. Additionally, a highly experienced safety/instructor pilot evaluated performance in terms of adherence to Aircrew Training Manual (ATM) standards (Department of the Army, 1984). Each type of performance measure was compared to every other type.

Method

Subjects

Twelve male Army aviators in good health were used as subjects. Each subject had at least 20/20 uncorrected vision with less than 1.0 diopter of refractive error, possessed normal hearing, and was between the ages of 24 and 32 (mean=29.1). Each received a complete physical examination to include a cardio-pulmonary function test and a cardiac stress test. All were tested for atropine sensitivity prior to participation in the study. Each subject was at least qualified in the UH-1 helicopter prior to selection for the study and was brought to currency during training flights.

Apparatus

Computerized in-flight evaluation

Two U. S. Army helicopters and a variety of integrated hardware and software were used to objectively evaluate pilot performance across a number of flight maneuvers. The primary aircraft, a U. S. Army UH-1H utility helicopter (Figure 1), was modified to allow in-flight data recording of all flight instruments, warning systems, and control movements. An aircraft in-flight monitoring system (AIMS) (Mitchell et al., 1988) was mounted in the cargo compartment (Figure 2). The secondary aircraft, an OH-58 helicopter, was used as a safety cover aircraft.

The AIMS software consisted of an interactive data acquisition program in which operator requests and screen updates were handled on a time-available basis, whereas sampling occurred in real time. The analog-to-digital converter setup, the display routines, and the calibration software were customized for the flight profile used. The following parameters were monitored: 1) barometric altitude, 2) airspeed, 3) cyclic fore-aft position, 4) cyclic left-right position, 5) collective position, 6) antitorque pedal position, 7) roll angle, 8) aircraft magnetic heading, 9) pitch attitude, 10) X-axis (longitudinal movement) accelerometer, 11) Y-axis (lateral movement) accelerometer, 12) Z-axis (vertical movement) accelerometer, 13) vertical airspeed, 14) ILS localizer indicator (runway centerline), 15) ILS glideslope indicator (approach angle), 16) engine torque, and 17) maneuver start/stop point marker.

Specialized software was written for the U.S. Army Aeromedical Research Laboratory's DEC VAX 11/780* computer system to read AIMS data tapes. The data were translated to interpretable units of measurement to facilitate subsequent data analyses. In addition, the VAX software permitted calibration of flight parameters, storage of parameter samples from each maneuver, computation of RMS error values and computer scores, calculation of summary statistics, and production of final data files.

Safety pilot evaluations

In addition to the computerized scoring system, a safety pilot rated the performance of each subject on each maneuver using a special rating form. There was a separate sheet for each maneuver on which the flight parameters for the specific maneuver could be evaluated in terms of how well the subject remained within prescribed limits (see Appendix B). The safety pilot

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*See list of manufacturers, Appendix A.

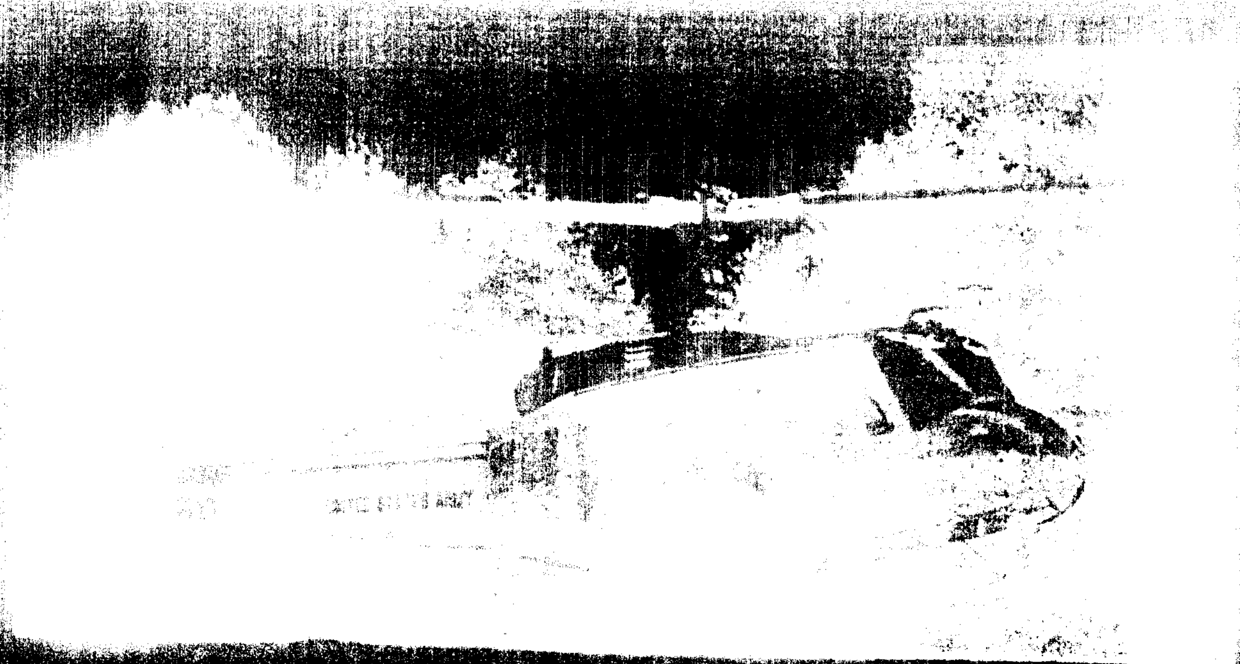

Figure 1. Instrumented UH-1H helicopter utilized for in-flight performance testing.

Figure 2. Aircraft in-flight monitoring system (AI[illegible]) [illegible]ated in the rear of the UH-1H helicopter.

simply circled the observed degree of deviation from the standard, and these were converted to a numerical scale for subsequent analysis. The same safety pilot was used for every flight.

Procedure

General

Each aviator was tested individually during a 9-11 day period which began with several training flights and continued through 3 dosage administration days, each of which was separated by a control day. On each of these training, dose, and control days, subjects flew the specially instrumented UH-1H helicopter and, between flights, completed a variety of laboratory tests. For the purposes of this report, only the flight segment will be discussed. A detailed description of the entire experiment can be found in Caldwell et al. (1991).

Adequate time for up to 3 complete training days was built into the investigation in order to guarantee that each subject had reached asymptotic performance on the standardized flight profile prior to administration of the first dose. At the conclusion of each flight, AIMS tapes were analyzed and compared to the data obtained from the preceding flight to determine if there was significant improvement attributable to practice. Once it was determined that performance had stabilized, the actual atropine testing began.

Testing consisted of 3 dose-administration days, each of which was separated by a single control day on which no flights were made, and only laboratory tests were conducted. On each dose-administration day, only one injection (either placebo or 2 mg or 4 mg of atropine) was administered i.m. into the right thigh. Each subject received all three injections according to a randomly assigned, counter-balanced dose-administration order in which the six orders were represented among both the first and second set of aviator participants (to permit a balanced preliminary analysis). Neither the subjects nor the researchers, with the exception of the principal investigator, were aware of which dose-administration sequence was used.

Each dose-administration (or test) day consisted of two helicopter flights interspersed with laboratory testing (described elsewhere). The drug (or placebo) injection was given immediately prior to the first flight of the day. There was no injection given prior to the second flight of the day which occurred approximately 5.5 hours postdose. Each flight was approximately 2 hours in length, and the sequence of maneuvers in each flight was held constant (see Table 1).

The control days which followed each dose-administration day were used primarily to ensure all atropine effects had subsided prior to the next dose. On these days, two complete in-house testing sessions were administered, but no atropine was given and no in-flight testing was conducted.

Flight performance evaluation

A safety pilot flying in the left seat of the research aircraft graded each subject's performance on certain maneuvers against standards established by the Aircrew Training Manual (Department of the Army, 1984). The grades consisted of scores ranging from 1 to 5, each associated with a particular level of flight performance accuracy (performance band). The bands were established around the ATM standards for each maneuver with a score of 3 being the standard for the performance measure in that maneuver. Scores higher than 3 represented performance which exceeded the minimum acceptable performance level and those below 3 represented substandard performance.

In addition to these safety-pilot grades, each subject's flight performance also was evaluated with the onboard computerized monitoring system described earlier.

Each subject began by flying a series of upper-air maneuvers sharing some commonality with more complex helicopter maneuvering tasks such as air-to-air combat, low-level flight, and nap-of-the-earth (NOE) flight. The aviators then moved on to the next portion of the flight profile, which simulated a common tactical mission of ingress into a forward battle position, and this was followed by a segment in which subjects navigated low-level and nap-of-the-earth courses. The final phase of the profile tested the pilot's ability to operate the aircraft after the majority of his visual cues were removed. While at NOE altitude, the subject was instructed to affix a hood to his helmet which restricted his view of the earth and forced him to fly using only the flight instruments. He then was directed to perform an immediate climb to altitude to simulate inadvertent flight into low-lying clouds after which he flew the last straight-and-level segment. The profile ended with a precision ILS approach to landing. All maneuvers within the profile were flown in the same order across all trials.

Results

Initial data processing

The flight performance data was processed differently depending upon whether it was computer-based or safety-pilot generated. Although in most cases, both the computer and the safety pilot scored the same measure (heading, airspeed, etc.), the safety-pilot grades were in final form at the conclusion of each flight whereas the computer data required additional processing. For the computer data, once all the raw flight performance data were collected, each measure (heading, airspeed, altitude, etc.) was scored within each maneuver to yield two types of outcome measures.

The first type of computer score was a root mean square (RMS) error calculation derived from the square root of the deviations from assigned values, divided by the number of samples within the specific maneuver. For instance, during straight-and-level maneuvers, subjects were told to fly at an altitude of 1000 feet (mean sea level), while maintaining a heading of 180 degrees and an airspeed of 90 knots. Thus, the ideal altitude value for this maneuver was 1000, and the subject's deviations from this ideal value were used to calculate the RMS error for altitude. The same procedure was used for the other measures (altitude, airspeed, etc).

The other type of computer score was a percentage value derived by first categorizing each sample of a given measure (heading, airspeed, etc.) into one of six bins ranging from worst to best (0 percent, 20 percent, 40 percent, 60 percent, 80 percent, or 100 percent) depending upon how far that sample deviated from a predetermined standard as shown in Table 2. At the conclusion of this first step, each bin contained one integer value which represented the number of samples classified into that particular bin. Then, the number of total samples collected on each measure (i.e., airspeed, altitude, climb rate, etc.) during each maneuver was determined. The number of samples in each bin was multiplied by the weighting factor for the respective bin (0, 20, 40, 60, 80, 100); the results were summed and then divided by the total number of samples. Thus, at the completion of this entire procedure, there was one performance score (expressed as a percentage) per measure per maneuver.

Data estimation

Some data required estimation because: 1) one subject's morning flight under the 4 mg dose of atropine was terminated for safety considerations; and 2) another subject's glideslope data were missing due to an equipment malfunction during three of the flights. In these two cases, the means of other subjects' data were substituted for the missing values.

Data transformation

All RMS errors, computer scores, and safety-pilot grades were transformed into z-scores prior to analysis. This step was not necessary for the calculation of the 1026 correlation coefficients, but it was done to place all data on the same scale for subsequent analyses. The z-score transformation does not, however, affect the magnitude of the Pearson r.

Data analysis

BMDP1R (Dixon et al., 1983) was used to calculate the correlation matrices for all measures collected across every maneuver within each flight. Analyses were performed on one flight at a time, for the total of six flights, with two flights on each dosage administration day for each of 3 days. From each matrix, only the relevant correlations were extracted. These correlations are presented in Tables 3-8. Note that each correlation is based upon 12 observations in each data pair, and this sample size requires a correlation coefficient of 0.497 for statistical significance at the 0.05 level, with 10 degrees of freedom, on a one-tailed test (Edwards, 1976).

Discussion

Relationship between computer measures

Of the 342 correlations between computer measures of flight performance (RMS errors versus percent scores), only 5 failed to attain significance. While this represents only a small fraction of the total, even the limited disagreement raised some cause for concern.

Subsequent examination of the data revealed that the reason for at least one of the nonsignificant findings was due to the lack of congruence between the RMS and percent values for 2 of the 12 subjects. Here, the roll measure was examined from the

morning flight of the 2-mg dose day, and it was found that the 2 subjects had virtually identical RMS errors, but had percent scores which differed by 25 points. The explanation for such a phenomenon resides in the method of calculation for the two types of computer scores. With the percent scores, samples are classified into discrete bands, one of which is scored as a 0. Once a subject exceeds a certain magnitude of control deviation, he receives a 0 whether he makes an error which slightly exceeds the critical value, or whether he makes an error which greatly exceeds the value. With the RMS errors, the amount of deviation is squared regardless of how large or small that deviation may be. Thus, a few very large control errors would significantly inflate the RMS error values whereas it would have a small effect on the percent scores. RMS errors are typically transformed into log naturals prior to analysis in order to minimize the inflation attributable to extreme values; however, this step was omitted when analyzing data for the purposes of this report.

The fact that the scores on roll control often were affected most by the problem outlined above was probably a function of individual differences in technique for controlling roll in turns. Also, aircraft roll is somewhat more difficult to stabilize than are other aspects of flight (such as airspeed and altitude).

Besides the discrepancies related to the roll measure, there was another instance in which the correlation coefficient was 0.0 because there was no variability in the RMS errors for that measure on one particular maneuver. This was because RMS errors were written to a data file with only two digits to the right of the decimal point, and slip fluctuations in this case were simply too small to be accurately reflected given that level of precision.

However, it should be noted, with the exception of these few instances, there was most often an extremely high level of agreement between the two computerized assessments of flight performance. This agrees with earlier assessments of these data, in which analysis of variance was performed on both types (RMS and percent), and the results were strikingly similar.

Relationship between RMS and safety-pilot grades

More central to the purpose of this report is the comparison between computer scoring of performance and safety-pilot evaluations. In the most global sense, it could be seen that out of the 342 correlations between RMS errors and safety-pilot grades, there were 171 which attained statistical significance. Thus, there was a reasonably strong relationship between computer and safety-pilot evaluations on at least 50 percent of the measures.

The picture improves further if correlations involving the slip measure are disregarded. As can be seen from examination of the Pearson *r*s for slip, the relationship often was 0.0. This is because there was frequently little variation in safety-pilot assessments of slip--subjects often received the highest scores during several maneuvers in each flight. In fact, we even experienced some problems with the computer scoring of slip which resulted in using a bandwidth so small that it stressed the level of measurement resolution available from the AIMS. This particular measure does not appear to be very sensitive.

Of the other available measures, there appeared to be a strong and relatively consistent agreement among computerized and safety-pilot assessments of altitude control. The correlation here between RMS errors and safety-pilot grades often ranged between -0.6 and -0.9, and the relationship did not appear to fluctuate substantially among the different flights. The relationship between the two types of airspeed scoring and the two types of heading scoring also was quite good.

In terms of the correlations which were not found to be significant, it should be said that the direction (positive/negative) of these correlations was generally the same as what was found with the significant *r*s. Counting correlations of 0.0 in the total number, 76 percent of the *r*s between RMS errors and safety-pilot grades were negative (the direction which would have been expected). Such a finding is encouraging since it suggests that a larger subject pool probably would have resulted in finding significant relationships between additional scores across other measures.

Relationship between percents and safety-pilot grades

The correlations between the computer-calculated percent scores and the safety-pilot grades showed a reasonably strong agreement as well. However, the strength of this relationship was not as good as what was found with RMS errors and safety-pilot grades. As mentioned, 171 of those correlations reached statistically significant levels, whereas only 136 of these (percents versus safety-pilot grades) met the critical value. Thus, once again a difference appears between the two types of measures calculated by the computer.

As was the case with RMS errors, examination of percent scores versus safety-pilot grades shows a reasonably strong relationship between the two when scoring altitude, airspeed, and heading control. Also, the number of significant correlations (across any measure) seems to be stable across the different flights regardless of the dose condition, and, here again, a large number of even the nonsignificant coefficients were found to be in the correct direction (positive).

Conclusions

Based upon close examination of the relationships between RMS errors and percent scores, RMS errors and safety-pilot grades, and percent scores and safety-pilot grades, the following conclusions may be drawn:

1. The two types of computer scoring of flight performance are very similar, but there are differences attributable to the way in which the two are calculated. RMS error values tend to be more heavily affected by extreme control deviations than are the percent scores. However, the practical effect of this difference usually is negligible.

2. Some of the low correlations (r=0.0) are explained by little or no variance in one of the two types of scores under consideration at the time. This was often attributable to inadequate scoring resolution for some measures (such as slip).

3. Of the two types of computer-generated flight evaluations, RMS errors were more strongly related to safety-pilot grades than were the percent scores. The reason for this finding probably relates to the greater numerical precision associated with calculation of RMS errors (these data weren't classified into discrete "bands").

4. Generally speaking, although the computer scoring and safety-pilot grading were not always significantly related in statistical terms, the correlations were in the expected direction. Thus, the relationship between RMS errors and safety-pilot grades was negative 76 percent of the time, and the relationship between percent scores and safety-pilot grades was positive 76 percent of the time.

5. Of the measures (heading, altitude, airspeed, roll, slip, etc.) under consideration, there was strongest agreement between the computer and the safety pilot when scoring airspeed control. Scoring of altitude control was second, and scoring of heading control was third.

Based upon these findings, it can be said that the two computer-generated scores are virtually interchangeable, but an increase in accuracy often is attainable with the RMS errors. Such an improvement will make a difference when establishing the relationship between computerized and human scoring of performance since improved precision in the former compensates for some loss of precision in the latter. Generally speaking, however, there was sufficient agreement between the computer and the safety pilot to indicate that both were scoring the same pilot performance in a fairly consistent manner. Such results lend credence to the hope that pilot performance may one day be assessed by strictly objective (computerized) methods.

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Appendix A

List of manufacturers

Digital Equipment Corporation
P.O. Box CS2008
Nasua, NH 03061-2008

Appendix B

Safety pilot grading sheet examples

Standard rate right turn

1. *Maintain altitude within 100 feet.*
   Altitude: (1) +/-300 (2) +/-200 (3) +/-100 (4) +/-50 (5) +/-0

2. *Maintain knots of indicated air speed within 10 knots.*
   Knots: (1) +/- 20 (2) +/- 15 (3) +/- 10 (4) +/- 5 (5) +/-0

3. *Maintain a constant standard rate of turn 80% of the time.*
   % Time: (1) <70% (2) 70% (3) 80% (4) 90% (5) 100%

4. *Roll out within 10 degrees of correct heading.*
   Heading: (1) +/- 20 (2) +/- 15 (3) +/- 10 (4) +/- 5 (5) +/-0

5. *Maintain aircraft in trim* 80% of the time.
   % Time: (1) <70% (2) 70% (3) 80% (4) 90% (5) 100%

Straight and level

1. *Maintain altitude within 100 feet.*
   Altitude: (1) +/-300 (2) +/-200 (3) +/-100 (4) +/-50 (5) +/-0

2. *Maintain knots indicated air speed within 10 knots.*
   Knots: (1) +/- 20 (2) +/- 15 (3) +/- 10 (4) +/- 5 (5) +/-0

3. *Maintain heading within 10 degrees of course.*
   Degrees: (1) +/- 20 (2) +/- 15 (3) +/- 10 (4) +/- 5 (5) +/-0

4. *Maintain aircraft in trim 80% of the time.*
   % Time: (1) <70% (2) 70% (3) 80% (4) 90% (5) 100%

Standard rate climb

1. *Maintain climb air speed at 90 kias within 10 knots.*
   Knots: (1) +/- 20 (2) +/- 15 (3) +/- 10 (4) +/- 5 (5) +/-0

2. *Maintain climb rate of 500 feet per minute within 100 fpm.*
   Fpm: (1) +/-300 (2) +/-200 (3) +/-100 (4) +/-50 (5) +/-0

3. *Maintain heading within 10 degrees of course.*
   Heading: (1) +/- 20 (2) +/- 15 (3) +/- 10 (4) +/- 5 (5) +/-0

4. *Level off within 50 feet of desired altitude.*
   Altitude: (1) +/-200 (2) +/-100 (3) +/- 50 (4) +/-25 (5) +/-0

5. *Maintain aircraft in trim 80% of the time.*
   % Time: (1) <70% (2) 70% (3) 80% (4) 90% (5) 100%

Appendix C

Tables

Table 1.

Precision in-flight maneuvering profile.

Hdg (deg)	Alt (ft)	A/S (kts)	Maneuver	Time from dose a.m.	p.m.
180	1000	90	Standard rate 360° right turn	00:14	05:38
180	1000	90	Straight-and-level no. 1 (2 min)	00:17	05:41
180	1000	90	Standard rate 360° left turn	00:20	05:44
180	1000	90	Straight-and-level no. 2 (2 min)	00:23	05:47
270	1000	90	Climb 500 feet per min to 2000'	00:27	05:51
270	2000	90	30° bank left turn 720°	00:31	05:55
270	2000	90	Straight-and-level no. 3 (2 min)	00:35	05:58
270	2000	90	30° bank right turn 900°	00:38	06:02
090	2000	90	Straight-and-level no. 4 (2 min)	00:42	06:06
090	2000	90	360° standard rate descending right turn to 1000'	00:45	06:10
090	1000	90	Straight-and-level no. 5 (2 min)	00:49	06:13
090	1000	90	360° standard rate climbing left turn to 2000'	00:52	06:16
na	2000	90	Descend 500 feet per min to 1000'	00:57	06:20
na	na	na	Confined area reconnoiter and approach		
na	na	na	Out-of-ground-effect hover		
na	na	na	Low-level navigation		
na	na	na	Nap-of-the-earth navigation		
na	na	na	Vertical helicopter IFR recovery procedure		
na	2000	90	Straight-and-level no. 6 (2 min)	01:52	07:11
060	2000	90	ILS approach	02:03	07:26

Table 2.

Scoring error bands.

Variable (units)	Band limits					
	0%	20%	40%	60%	80%	100%
Heading (Degrees)	12.000-999.000	6.000- 12.000	3.000- 6.000	1.500- 3.000	0.750- 1.500	0.000- 0.750
Altitude (Feet)	140.000-999.000	70.000-140.000	35.000- 70.000	17.500- 35.000	8.750- 17.500	0.000- 8.750
Airspeed (Knots)	16.000-999.000	8.000- 16.000	4.000- 8.000	2.000- 4.000	1.000- 2.000	0.000- 1.000
Climb rate (Ft/min)	800.000-999.000	400.000-800.000	200.000-400.000	100.000-200.000	50.000-100.000	0.000-50.000
Pitch (Degrees)	6.000-999.000	3.000- 6.000	1.500- 3.000	0.750- 1.500	0.375- 0.750	0.000- 0.375
Roll (Degrees)	8.000-999.000	4.000- 8.000	2.000- 4.000	1.000- 2.000	0.500- 1.000	0.000- 0.500
Slip (Gs)	0.060-999.000	0.030- 0.060	0.015- 0.030	0.008- 0.015	0.004- 0.008	0.000- 0.004
Localizer (Dots)	3.800-999.000	1.900- 3.800	0.950- 1.950	0.475- 0.950	0.238- 0.475	0.000- 0.238
Glideslope (Dots)	3.800-999.000	1.900- 3.800	0.950- 1.950	0.475- 0.950	0.238- 0.475	0.000- 0.238

Table 3.

Correlations for the placebo dose during the AM flight.

	RMS vs percent scores	RMS vs safety pilot grades	Percent vs safety pilot grades
RIGHT TURN			
Altitude	-.9491	-.8754	.7021
Airspeed	-.9410	-.4383	.4213
Roll (Turn Rate)	-.8974	.4384	-.2393
Slip (Trim)	-.8588	.0000	.0000
STRAIGHT/LEVEL #1			
Heading	-.9679	-.3018	.2658
Altitude	-.9459	-.7665	.7112
Airspeed	-.9266	-.2625	.1425
Slip (Trim)	-.8205	.0000	.0000
LEFT TURN			
Altitude	-.9467	-.3812	.3692
Airspeed	-.9898	-.5637	.5596
Roll (Turn)	-.9168	-.3639	.4132
Slip (Trim)	-.8619	-.1606	.1923
STRAIGHT/LEVEL #2			
Heading	-.9730	-.3809	.3871
Altitude	-.9493	-.6999	.7680
Airspeed	-.9909	-.7017	.7393
Slip (Trim)	-.7889	.0000	.0000
STRAIGHT CLIMB			
Heading	-.9165	-.5260	.4935
Airspeed	-.9501	-.6640	.6008
VS (Climb rate)	-.9405	-.4792	.3537
Slip (Trim)	-.8316	.0000	.0000
STEEP LEFT TURN			
Altitude	-.9609	-.6869	.6783
Airspeed	-.9186	-.6816	.5937
Roll (Turn)	-.7677	-.3523	.2453
Slip (Trim)	-.9677	-.6247	.5771
STRAIGHT/LEVEL #3			
Heading	-.9599	.1607	-.1068
Altitude	-.9411	.0060	.0066
Airspeed	-.9874	-.4145	.4349
Slip (Trim)	-.8992	-.2739	.4400
STEEP RIGHT TURN			
Altitude	-.9697	-.5975	.6430
Airspeed	-.9671	-.6710	.6687
Roll (Turn)	-.5397	-.1121	.1563
Slip (Trim)	-.9187	-.1690	-.0212

Table 3 (continued).

STRAIGHT/LEVEL #4			
Heading	-.9509	-.8325	.6798
Altitude	-.9249	-.8293	.6920
Airspeed	-.9699	-.7744	.7369
Slip (Trim)	-.8622	.0000	.0000
RIGHT DESCENDING TURN			
Airspeed	-.9684	-.7798	.8092
VS (Desc. rate)	-.9064	-.5512	.6339
Roll (Turn)	-.6177	-.6913	.2884
STRAIGHT/LEVEL #5			
Heading	-.9429	-.4463	.2663
Altitude	-.9522	-.0601	.0658
Airspeed	-.9530	-.6884	.5553
Slip (Trim)	-.8480	.0000	.0000
LEFT CLIMBING TURN			
Airspeed	-.9025	-.9440	.8251
VS (Desc. rate)	-.9581	-.5358	.5716
Roll (Turn)	-.4882	-.1828	-.0924
STRAIGHT DESCENT			
Heading	-.9750	.0000	.0000
Airspeed	-.9628	-.6601	.5169
VS (Climb rate)	-.9484	-.3481	.4636
Slip (Trim)	-.6932	.0000	.0000
STRAIGHT/LEVEL #6			
Heading	-.8248	-.3275	-.0877
Altitude	-.9482	-.7913	.7407
Airspeed	-.9412	-.6511	.4213
Slip (Trim)	-.7935	.0000	.0000
ILS			
Airspeed	-.9625	-.6926	.7093
Localizer	-.7983	-.8285	.5325
Glideslope	-.9638	-.7655	.6452

Table 4.

Correlations for the placebo dose during the PM flight.

	RMS vs percent scores	RMS vs safety pilot grades	Percent vs safety pilot grades
RIGHT TURN			
Altitude	-.8809	-.9070	.7820
Airspeed	-.9478	-.5899	.4427
Roll (Turn)	-.8408	-.4987	.4677
Slip (Trim)	-.8051	.0000	.0000
STRAIGHT/LEVEL #1			
Heading	-.9445	-.2038	.2638
Altitude	-.8786	-.8496	.6334
Airspeed	-.9295	-.6970	.5909
Slip (Trim)	-.8887	.0000	.0000
LEFT TURN			
Altitude	-.9571	-.7545	.7123
Airspeed	-.9910	-.8534	.8077
Roll (Turn)	-.8767	.2173	-.2830
Slip (Trim)	-.8625	.0000	.0000
STRAIGHT/LEVEL #2			
Heading	-.9348	-.9132	.7924
Altitude	-.8778	-.5095	.1102
Airspeed	-.9669	-.7381	.6345
Slip (Trim)	-.9284	.0000	.0000
STRAIGHT CLIMB			
Heading	-.9427	-.3276	.2804
Airspeed	-.8779	-.5509	.2677
VS (Climb rate)	-.9750	-.3205	.3856
Slip (Trim)	-.8076	.0000	.0000
STEEP LEFT TURN			
Altitude	-.9385	-.8664	.7870
Airspeed	-.9227	-.7529	.5658
Roll (Turn)	-.5040	-.0884	.4093
Slip (Trim)	-.9358	.0842	-.2187
STRAIGHT/LEVEL #3			
Heading	-.9461	.0000	.0000
Altitude	-.9553	-.7088	.6038
Airspeed	-.9891	-.7391	.6958
Slip (Trim)	-.8308	.0000	.0000
STEEP RIGHT TURN			
Altitude	-.9425	-.4831	.4691
Airspeed	-.8956	-.7804	.6280
Roll (Turn)	-.6065	-.3528	.5056
Slip (Trim)	-.9210	.0000	.0000

Table 4 (continued).

STRAIGHT/LEVEL #4			
Heading	-.9889	-.4980	.4007
Altitude	-.9485	-.7451	.5506
Airspeed	-.9894	-.7328	.7170
Slip (Trim)	-.5753	.0000	.0000
RIGHT DESCENDING TURN			
Airspeed	-.9389	-.7457	.6746
VS (Desc. rate)	-.9308	.0774	-.2178
Roll (Turn)	-.7231	-.2546	.2999
STRAIGHT/LEVEL #5			
Heading	-.9439	-.2300	.1133
Altitude	-.9463	.0000	.0000
Airspeed	-.9970	-.7203	.7020
Slip (Trim)	-.7450	.0000	.0000
LEFT CLIMBING TURN			
Airspeed	-.9322	-.6959	.5674
VS (Desc. rate)	-.9708	-.3207	.2921
Roll (Turn)	-.8103	-.0535	.2706
STRAIGHT DESCENT			
Heading	-.9763	-.9500	.8742
Airspeed	-.8728	-.0855	-.2800
VS (Climb rate)	-.9314	-.2920	.4079
Slip (Trim)	-.8504	-.6364	.7753
STRAIGHT/LEVEL #6			
Heading	-.9595	.0113	-.0121
Altitude	-.9881	-.2965	.2571
Airspeed	-.9669	-.5354	.6144
Slip (Trim)	-.8917	.0000	.0000
ILS			
Airspeed	-.9459	-.9137	.8308
Localizer	-.9190	-.7315	.5721
Glideslope	-.9648	-.8189	.7428

Table 5.

Correlations for the 2-mg dose during the AM flight.

	RMS vs percent scores	RMS vs safety pilot grades	Percent vs safety pilot grades
RIGHT TURN			
Altitude	-.8862	-.4166	.1236
Airspeed	-.9520	-.6003	.6562
Roll (Turn Rate)	-.7047	.0000	.0000
Slip (Trim)	-.9020	.0000	.0000
STRAIGHT/LEVEL #1			
Heading	-.9429	-.3198	.2569
Altitude	-.9780	.0000	.0000
Airspeed	-.9790	-.4367	.3486
Slip (Trim)	-.9482	.1606	-.1576
LEFT TURN			
Altitude	-.9307	-.5531	.3978
Airspeed	-.9795	-.4619	.4686
Roll (Turn)	-.9120	.0246	-.1002
Slip (Trim)	-.9645	.0000	.0000
STRAIGHT/LEVEL #2			
Heading	-.9539	-.3643	.1406
Altitude	-.9803	-.5746	.4434
Airspeed	-.9759	-.6141	.6303
Slip (Trim)	-.9514	.0000	.0000
STRAIGHT CLIMB			
Heading	-.9680	-.2937	.2941
Airspeed	-.9744	-.7874	.7952
VS (Climb rate)	-.9796	.0555	-.1039
Slip (Trim)	-.9019	.0000	.0000
STEEP LEFT TURN			
Altitude	-.9362	-.2157	.3727
Airspeed	-.9817	-.5734	.5941
Roll (Turn)	-.4456	.2235	.3599
Slip (Trim)	-.9233	-.4540	.4165
STRAIGHT/LEVEL #3			
Heading	-.8773	.0000	.0000
Altitude	-.9489	.0000	.0000
Airspeed	-.9757	-.8201	.7585
Slip (Trim)	-.8862	.0000	.0000
STEEP RIGHT TURN			
Altitude	-.9507	-.7980	.8080
Airspeed	-.9188	-.6393	.3669
Roll (Turn)	-.5035	.0613	.2034
Slip (Trim)	-.6554	-.5222	.1860

Table 5 (continued).

STRAIGHT/LEVEL #4			
Heading	-.9780	.0000	.0000
Altitude	-.9834	-.4629	.3842
Airspeed	-.9789	-.6305	.5819
Slip (Trim)	-.8546	.0000	.0000
RIGHT DESCENDING TURN			
Airspeed	-.9431	.8053	.6419
VS (Desc. rate)	-.9207	-.2448	.1569
Roll (Turn)	-.8165	-.1597	.1558
STRAIGHT/LEVEL #5			
Heading	-.9838	-.6172	.5894
Altitude	-.8923	-.8621	.6643
Airspeed	-.9551	-.6748	.6548
Slip (Trim)	.0000	.0000	.0000
LEFT CLIMBING TURN			
Airspeed	-.8881	.0000	.0000
VS (Desc. rate)	-.9666	-.1747	.3331
Roll (Turn)	-.8374	-.3860	.5282
STRAIGHT DESCENT			
Heading	-.9705	-.7174	.6336
Airspeed	-.9382	-.6878	.4736
VS (Climb rate)	-.9640	-.1708	.2452
Slip (Trim)	-.6826	.0000	.0000
STRAIGHT/LEVEL #6			
Heading	-.7131	-.7482	.5421
Altitude	-.9406	-.5721	.5393
Airspeed	-.9320	.0092	-.2099
Slip (Trim)	-.8036	-.6414	.5293
ILS			
Airspeed	-.8807	-.5475	.5042
Localizer	-.8855	-.5642	.4858
Glideslope	-.7689	-.5625	.6868

Table 6.

Correlations for the 2-mg dose during the PM flight.

	RMS vs percent scores	RMS vs safety pilot grades	Percent vs safety pilot grades
RIGHT TURN			
Altitude	-.9163	-.7625	.5584
Airspeed	-.9317	-.8061	.8501
Roll (Turn)	-.7991	-.3681	.3846
Slip (Trim)	-.8726	.0000	.0000
STRAIGHT/LEVEL #1			
Heading	-.9839	-.4749	.4450
Altitude	-.7313	-.4835	.1009
Airspeed	-.8680	-.4442	.6481
Slip (Trim)	-.6679	.0909	.1199
LEFT TURN			
Altitude	-.8762	-.6101	.2843
Airspeed	-.9813	-.4595	.4748
Roll (Turn)	-.9045	-.4995	.2771
Slip (Trim)	-.8764	-.3220	-.0031
STRAIGHT/LEVEL #2			
Heading	-.9792	-.7472	.7203
Altitude	-.9234	-.8398	.5945
Airspeed	-.9528	-.7952	.6803
Slip (Trim)	-.8561	-.6916	.4802
STRAIGHT CLIMB			
Heading	-.9709	.0000	.0000
Airspeed	-.9687	-.7301	.7086
VS (Climb rate)	-.9655	-.2743	.2720
Slip (Trim)	-.[illegible]369	.1267	-.0252
STEEP LEFT TURN			
Altitude	-.9492	-.4898	.4972
Airspeed	-.8948	-.7522	.7660
Roll (Turn)	-.9201	-.6140	.5804
Slip (Trim)	-.8945	-.5078	.3470
STRAIGHT/LEVEL #3			
Heading	-.9495	-.8561	.6710
Altitude	-.9692	-.7093	.6196
Airspeed	-.9044	-.4815	.4544
Slip (Trim)	-.8943	-.7741	.6640
STEEP RIGHT TURN			
Altitude	-.9500	-.5418	.5105
Airspeed	-.9735	-.6156	.5281
Roll (Turn)	-.5902	-.6331	.9366
Slip (Trim)	-.9228	-.7539	.6140

Table 6 (continued).

STRAIGHT/LEVEL #4			
Heading	-.9598	-.7691	.6641
Altitude	-.9382	-.8138	.7533
Airspeed	-.9508	-.2040	.0661
Slip (Trim)	-.9049	-.3206	.2959
RIGHT DESCENDING TURN			
Airspeed	-.8987	-.6676	.6435
VS (Desc. rate)	-.7189	-.4696	.1863
Roll (Turn)	-.6828	-.4813	.3880
STRAIGHT/LEVEL #5			
Heading	-.9773	-.2159	.2232
Altitude	-.9143	-.0869	-.2285
Airspeed	-.9833	-.3641	.3313
Slip (Trim)	-.8055	.0573	.3762
LEFT CLIMBING TURN			
Airspeed	-.9654	-.5769	.6498
VS (Desc. rate)	-.9610	.0565	.1235
Roll (Turn)	-.6452	.1283	.1247
STRAIGHT DESCENT			
Heading	-.9381	-.6693	.5023
Airspeed	-.9851	-.3951	.4251
VS (Climb rate)	-.9192	-.8000	.7515
Slip (Trim)	-.8769	-.5386	.5085
STRAIGHT/LEVEL #6			
Heading	-.4157	-.7162	.4654
Altitude	-.9728	-.6304	.5145
Airspeed	-.9404	-.7196	.5839
Slip (Trim)	-.9372	.0000	.0000
ILS			
Airspeed	-.9595	-.9364	.8766
Localizer	-.9703	-.7639	.8072
Glideslope	-.9405	-.9228	.9121

Table 7.

Correlations for the 4-mg dose during the AM flight.

	RMS vs percent scores	RMS vs safety pilot grades	Percent vs safety pilot grades
RIGHT TURN			
Altitude	-.9349	-.8327	.7208
Airspeed	-.9508	-.5857	.6884
Roll (Turn Rate)	-.6866	-.4047	.0405
Slip (Trim)	-.9265	.0000	.0000
STRAIGHT/LEVEL #1			
Heading	-.9518	-.8356	.7309
Altitude	-.9408	-.5132	.3502
Airspeed	-.8647	.1963	-.1576
Slip (Trim)	-.9417	.0510	-.0889
LEFT TURN			
Altitude	-.9321	-.5037	.4825
Airspeed	-.9781	-.4091	.4597
Roll (Turn)	-.7709	-.5688	.1126
Slip (Trim)	-.9209	.0000	.0000
STRAIGHT/LEVEL #2			
Heading	-.9715	-.4116	.2413
Altitude	-.9603	-.4031	.3334
Airspeed	-.9324	-.5096	.4754
Slip (Trim)	-.9666	.0000	.0000
STRAIGHT CLIMB			
Heading	-.9458	-.3780	.3812
Airspeed	-.9692	-.4242	.4302
VS (Climb rate)	-.9770	-.0726	.0455
Slip (Trim)	-.9226	-.5265	.4507
STEEP LEFT TURN			
Altitude	-.9319	-.6425	.5194
Airspeed	-.9472	-.5480	.4456
Roll (Turn)	-.7157	-.1227	.4026
Slip (Trim)	-.9021	-.6402	.5417
STRAIGHT/LEVEL #3			
Heading	-.9469	.0000	.0000
Altitude	-.8374	-.8079	.5586
Airspeed	-.9792	-.2138	.1470
Slip (Trim)	-.7970	.1909	-.0132
STEEP RIGHT TURN			
Altitude	-.9820	-.1577	.1664
Airspeed	-.8795	-.7150	.4144
Roll (Turn)	-.7833	-.3303	.6034
Slip (Trim)	-.8853	-.5855	.7464

Table 7 (continued).

STRAIGHT/LEVEL #4			
Heading	-.9685	.0000	.0000
Altitude	-.9642	-.5556	.4598
Airspeed	-.9777	-.5538	.4133
Slip (Trim)	-.8645	.0000	.0000
RIGHT DESCENDING TURN			
Airspeed	-.9431	-.3083	.1619
VS (Desc. rate)	-.9736	-.5999	.4978
Roll (Turn)	-.2780	-.3032	.2108
STRAIGHT/LEVEL #5			
Heading	-.9450	.1417	-.1607
Altitude	-.9436	-.4411	.3594
Airspeed	-.9527	-.1637	.3774
Slip (Trim)	-.7701	.0997	-.0092
LEFT CLIMBING TURN			
Airspeed	-.9569	-.4666	.5031
VS (Desc. rate)	-.9024	.3343	-.5715
Roll (Turn)	-.7492	-.5397	.4250
STRAIGHT DESCENT			
Heading	-.9280	-.6604	.4833
Airspeed	-.9588	-.5717	.4361
VS (Climb rate)	-.8676	.1120	-.0355
Slip (Trim)	-.8844	.2237	-.0993
STRAIGHT/LEVEL #6			
Heading	-.9753	-.0731	.1454
Altitude	-.8879	-.8472	.8214
Airspeed	-.9744	-.0051	.0028
Slip (Trim)	-.9119	-.7121	.6535
ILS			
Airspeed	-.9859	-.8791	.8698
Localizer	-.8136	-.7074	.2631
Glideslope	-.9344	-.8640	.7620

Table 8.

Correlations for the 4-mg dose during the PM flight.

	RMS vs percent scores	RMS vs safety pilot grades	Percent vs safety pilot grades
<u>RIGHT TURN</u>			
Altitude	-.8804	-.7096	.5726
Airspeed	-.9866	-.7498	.7208
Roll (Turn)	-.8944	-.6929	.4529
Slip (Trim)	-.8938	.0000	.0000
<u>STRAIGHT/LEVEL #1</u>			
Heading	-.9658	-.5823	.6599
Altitude	-.8835	-.5117	.3134
Airspeed	-.9486	-.6505	.6840
Slip (Trim)	-.7532	-.5606	.3117
<u>LEFT TURN</u>			
Altitude	-.8724	-.6565	.5005
Airspeed	-.9591	-.6358	.6140
Roll (Turn)	-.8710	-.7361	.7128
Slip (Trim)	-.8277	.1267	-.1194
<u>STRAIGHT/LEVEL #2</u>			
Heading	-.9052	-.7595	.5625
Altitude	-.9579	-.7335	.7910
Airspeed	-.9565	-.6280	.5673
Slip (Trim)	-.9505	.0000	.0000
<u>STRAIGHT CLIMB</u>			
Heading	-.9300	-.2314	.1410
Airspeed	-.9546	-.2910	.3174
VS (Climb rate)	-.9217	.1613	-.1416
Slip (Trim)	-.8799	.2335	-.3945
<u>STEEP LEFT TURN</u>			
Altitude	-.9866	-.4538	.3713
Airspeed	-.9648	-.7455	.7118
Roll (Turn)	-.6902	-.6178	.8162
Slip (Trim)	-.9088	.0000	.0000
<u>STRAIGHT/LEVEL #3</u>			
Heading	-.9841	.0117	.0184
Altitude	-.9643	-.7819	.7112
Airspeed	-.8823	-.8368	.7680
Slip (Trim)	-.7903	.0510	-.2646
<u>STEEP RIGHT TURN</u>			
Altitude	-.9624	-.3824	.3868
Airspeed	-.9305	-.7204	.8257
Roll (Turn)	-.5398	-.6176	.7923
Slip (Trim)	-.9061	-.1634	.2611

Table 8 (continued).

STRAIGHT/LEVEL #4			
Heading	-.9432	-.0817	.2553
Altitude	-.9650	-.8006	.6775
Airspeed	-.9810	-.8374	.8341
Slip (Trim)	-.9120	-.0386	-.1195
RIGHT DESCENDING TURN			
Airspeed	-.9887	-.6926	.6409
VS (Desc. rate)	-.9174	-.2532	-.0044
Roll (Turn)	-.7098	-.5859	.7746
STRAIGHT/LEVEL #5			
Heading	-.9930	-.6240	.5912
Altitude	-.9337	-.8495	.6381
Airspeed	-.9558	.0687	-.0127
Slip (Trim)	-.8705	.1611	.2645
LEFT CLIMBING TURN			
Airspeed	-.9773	-.8416	.8018
VS (Desc. rate)	-.9267	-.6937	.6943
Roll (Turn)	-.6073	.0992	.4186
STRAIGHT DESCENT			
Heading	-.9681	-.7082	.6103
Airspeed	-.9605	-.4581	.3989
VS (Climb rate)	-.9641	-.8271	.8182
Slip (Trim)	-.8040	.0391	-.3026
STRAIGHT/LEVEL #6			
Heading	-.7409	-.8605	.4356
Altitude	-.9253	-.6231	.3934
Airspeed	-.9769	-.5841	.4176
Slip (Trim)	-.9421	-.0255	.2392
ILS			
Airspeed	-.9777	-.7652	.7445
Localizer	-.8768	-.6682	.4277
Glideslope	-.8939	-.7726	.6223

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